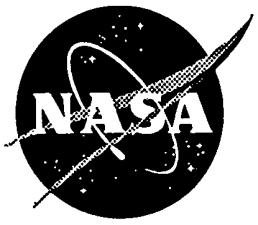


National Aeronautics and
Space Administration

HYBRID

NASA-STD-8739.4
February 1998

PREVIOUS VERSION PUBLISHED AS NAS 5300.4(3G-1)

# CRIMPING, INTERCONNECTING CABLES, HARNESSES, AND WIRING

NASA TECHNICAL STANDARD

# FOREWORD

Effective Date: February 9, 1998

This Standard provides a baseline for NASA project offices to use when preparing or evaluating process procedures for the manufacture of space flight hardware or mission critical ground support equipment.

This Standard:

a. Prescribes NASA's process and end-item requirements for reliable crimped connections, interconnecting cables, harnesses, and wiring.

b. Establishes responsibilities for training personnel.

c. Establishes responsibilities for documenting process procedures including supplier innovations, special processes, and changes in technology.

d. For the purpose of this Standard, the term supplier is defined as in-house NASA, NASA contractors, and subtier contractors.

NASA Installations shall:

a. Review and invoke the provisions of this Standard for procurements involving crimped connections, interconnecting cables, harnesses, or wiring of space flight hardware and mission critical ground support equipment.

b. Review and invoke the provisions of this Standard for in-house operations involving crimped connections, interconnecting cables, harnesses, or wiring of space flight hardware and mission critical ground support equipment.

c. Tailor specific provisions of this Standard to address program or unique contractual or mission requirements.

d. Assure that NASA suppliers invoke this Standard on subcontractors, purchase orders, and on subtier suppliers where applicable.

e. Furnish copies of this Standard in the quantities required to NASA suppliers and subtier suppliers.

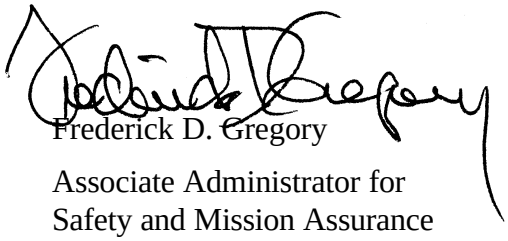
Questions concerning the application of this Standard to specific procurements shall be referred to the procuring NASA installation, or its designated representative.

This Standard cancels NASA Assurance Standard (NAS) 5300.4(3G-1), Workmanship Standard for Interconnecting Cables, Harnesses, and Wiring, and NASA Handbook (NHB) 5300.4(3H), Requirements for Crimping and Wire Wrap.

This Standard shall not be rewritten or reissued in any other form not approved by NASA.

Other processes not covered by this standard may be required. The design, materials, and processes shall be defined in engineering documentation.

Comments and suggestions for improving this Standard may be submitted using the form "NASA Technical Standard Improvement Proposal." A copy of this form is included at the end of this standard.



Frederick D. Gregory

Associate Administrator for
Safety and Mission Assurance

DISTRIBUTION:

SDL1 (SIQ)

# NASA TECHNICAL STANDARDS FOR SPACE FLIGHT AND MISSION CRITICAL GROUND SUPPORT HARDWARE

NASA Technical Standards can be found on the World Wide Web at URL address http://www/hq.nasa.gov/office/codeq/qdoc.pdf.

| Title | Number |
|---|---|
| Soldered Electrical Connections | NASA-STD-8739.3 |
| Crimping, Interconnecting Cables, Harnesses, and Wiring | NASA-STD-8739.4 |
| Fiber Optic Terminations, Cable Assemblies, and Installation | NASA-STD-8739.5 |
| Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies | NAS 5300.4(3J-1) |
| Workmanship Standard for Surface Mount Technology | NAS 5300.4(3M) |
| Standard for Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices) | NASA-STD-8739.7 |

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# CHAPTER 1 - SCOPE

## 1.1 Purpose

1 This publication sets forth requirements for interconnecting cable and harness assemblies that connect electrical/electronic and electromechanical components.

2. Special requirements may exist that are not covered by or are not in conformance with the requirements of this publication. Engineering documentation shall contain the details for such requirements, including modifications to existing hardware, and shall take precedence over appropriate portions of this publication when approved in writing by the procuring NASA Center prior to use.

## 1.2 Applicability

This publication is applicable to NASA programs involving interconnecting cable and wire harnesses for flight hardware, mission critical ground support equipment, and elements thereof, and wherever invoked contractually.

# CHAPTER 2 - APPLICABLE DOCUMENTS

## 2.1 Applicable Specifications

Copies of the following specifications, when required in connection with a specific procurement, can be obtained from the procuring NASA Center or as directed by the contracting officer. Unless otherwise specified, the issue in effect on the date of invitation for bids or requests for proposal shall apply. The following related documents form a part of this publication to the extent specified herein.

FEDERAL SPECIFICATIONS:

| | |
|---|---|
| TT-I-735 | Isopropyl Alcohol |
| O-E-760 | Ethyl Alcohol (Ethanol) Denatured Alcohol; Proprietary Solvents and Special Industrial Solvents |

NASA SPECIFICATIONS:

| | |
|---|---|
| MIL-STD-975 | NASA Standard EEE Parts List |
| NASA-STD-8739.7 | NASA Technical Standard for Electrostatic Discharge Control (Excluding Electronically Initiated Explosive Devices) |
| NHB 1700.1(V1) | NASA Safety Policy and Requirements Document |
| NHB 8060.1C | Flammability, Odor, and Offgassing Requirements and Test Procedures for Materials in Environments that Support Combustion |
| NASA-STD-8739.3 | NASA Technical Standard for Soldered Electrical Connections |

NATIONAL STANDARDS:

American National Standards Institute (ANSI):

| | |
|---|---|
| ANSI/NCSL Z540-1-1994 | General Requirements for Calibration Laboratories and Measuring and Test Equipment |

American Society for Testing and Materials (ASTM)

| | |
|---|---|
| ASTM-E-595 | Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment |

## 2.2 Other Documents:

Industrial Ventilation: A Manual of Recommended Practice.
Published by the American Conference of Governmental Industrial Hygienists;
1330 Kemper Meadow Drive; Cincinnati, OH 45240.
URL http://www.acgih.org

Occupational Safety and Health Administration, 29 CFR.

# CHAPTER 3 - DEFINITIONS AND ACRONYMS

## 3.1 Definitions

The following definitions apply to terms used in this Standard.

**Accessories**. Mechanical devices, such as cable clamps, added to connector bodies.

**Adapter.** An intermediate device to provide for attaching special accessories or to provide special mounting means.

**Barrel (Contact Wire Barrel).** The section of contact that accommodates the stripped conductor.

**Birdcaging**. The radial expansion of individual strands in a stranded conductor (bowing outward) that can occur in the exposed portion of the conductor between the insulation strip and termination point.

**Braid**. A fibrous or metallic group of filaments interwoven to form a protective covering over one or more wires.

**Breakout**. The separation of a conductor or group of conductors from the main body of wires in a harness.

**Bubble Pack**. A laminated plastic sheet that is formed with patterned air entrapment ("bubbles"). The bubbles provide excellent cushioning for anything enclosed between layers of the material.

**Cable**. A shielded single conductor or a combination of conductors insulated from one another (multiple conductor).

**Cable, Coaxial**. A cable in which an insulated conductor is centered inside another. The outer conductor is usually a metal braid or metal sheath. Braided cables usually have an outer insulating jacket over the braid. Coaxial cables are used primarily for transmission of RF signals.

**Cable, Shielded**. One or more insulated conductors covered with a metallic outer covering, usually a metal braid.

**Cable Clamp**. A mechanical clamp attached to the wire entrance of a connector to support the cable or wire bundle, provide stress relief, and absorb vibration and shock.

**Certification**. The act of verifying and documenting that personnel have completed required training, have demonstrated specified proficiency, and have met other specified requirements.

**Cold Flow**. Movement of insulation (e.g., Teflon) caused by pressure.

**Conductor**. A lead or wire, solid, stranded, or printed wiring path serving as an electrical connection.

**Connector, Body**. The main portion of a connector to which contacts and other accessories are attached.

**Connector, Grommet**. An elastomeric seal used on the cable side of a connector body to seal the connector against contamination and to provide stress relief.

**Connector, Insert**. The part of a connector that holds the contacts in position and electrically insulates them from each other and the shell.

**Contact**. The conductive element in a connector or other terminal device that mates with a corresponding element for the purpose of transferring electrical energy.

**Contact, Crimp**. A contact whose crimp barrel is a hollow cylinder that accepts the conductor. After a conductor has been inserted, a tool is used to crimp the contact metal firmly onto the conductor.

**Contact, Insertable/Removable**. A contact that can be mechanically joined to or removed from an insert. Usually, special tools are used to insert (lock) the contact into place or to remove it.

**Contact, Pin**. Male-type contact designed to slip inside a socket contact.

**Contact Retention**. The axial load in either direction that a contact can withstand without being dislodged from its normal position within an insert or body.

**Contact, Socket**. A female-type contact designed to slip over a pin contact.

**Contaminant**. An impurity or foreign substance present in a material that affects one or more properties of the material. A contaminant may be either ionic or nonionic. An ionic, or polar compound, forms free ions when dissolved in water, making the water a more conductive path. A nonionic substance does not form free ions, nor increase the water's conductivity. Ionic contaminants are usually processing residue such as flux activators, finger prints, and etching or plating salts.

**Crimp**. The physical compression (deformation) of a contact barrel around a conductor to make an electrical and mechanical connection to the conductor.

**Crimping**. A method of mechanically compressing or securing a terminal, splice, or contact to a conductor.

**Drain Wire**. A wire that runs linearly along a foil shield wire or cable and is used to make contact with the shield. Grounding of foil shields is done with drain wires.

**Electromagnetic Interference**. The unwanted intrusion of electromagnetic radiation energy whose frequency spectrum extends from subsonic frequency to X-rays.

**Ferrule**. A short metal tube used to make crimp connections to shielded or coaxial cables.

**Fillet**. A smooth concave buildup of material between two surfaces; e.g., a fillet of solder between a conductor and a solder terminal.

**Grommet**. An insulator that covers sharp edges of holes through panels and partitions to protect wire insulation from cut-through damage.

**Harness**. One or more insulated wires or cables, with or without helical twist; with or without common covering, jacket, or braid; with or without breakouts; assembled with two or more electrical termination devices; and so arranged that as a unit it can be assembled and handled as one assembly.

**Insertion Tool.** A device used to install contacts into a contact cavity in a connector insert.

**Interfacial Seal**. A sealing of mated connectors over the whole area of the interface to provide sealing around each contact.

**Jacket**. The outermost layer of insulating material of a cable or harness.

**Joint**. A termination.

**Mate**. The joining of two connectors.

**Molding**. The sealing of a connector backshell area or a cable breakout with a compound or material that excludes moisture and provides stress relief. The material is injected into molds that control its configuration.

**Offgassing**. The release of a volatile part(s) from a substance when placed in a vacuum environment that may affect crew members.

**Outgassing**. The release of a volatile part(s) from a substance when placed in a vacuum environment.

**Radio Frequency**. The frequency spectrum from 15 kHz to 100 GHz. Cables are seldom used above 18 GHz.

**Radio Frequency Interference**. Electromagnetic radiation in the radio frequency spectrum from 15 kHz to 100 GHz.

**Sealing Plug**. A plug that is inserted to fill an unoccupied contact aperture in a connector. Its function is to seal an unoccupied aperture in the assembly, especially in environmental connectors.

**Shielded Cable**. Cable surrounded by a metallic covering intended to minimize the effects of electrical crosstalk interference or signal radiation.

**Shielding**. The metal covering surrounding one or more conductors in a circuit to prevent interference or signal radiation.

**Solder**. A nonferrous, fusible metallic alloy used to join metallic surfaces.

**Solder Cup Terminal**. A hollow, cylindrical terminal designed to accommodate one or more conductors.

**Soldering**. The process of joining clean metallic surfaces through the use of solder without direct fusion of the base metals.

**Solder Sleeve**. A heat-shrinkable solder termination device with meltable sealing preforms at ends.

**Splice**. The joining of two or more conductors to each other.

**Spacecraft**. Devices, manned or unmanned, which are designed to be placed into a suborbital trajectory, an orbit about the earth, or into a trajectory to another celestial body.

**Strain Relief**. A connector device that prevents the disturbance of the contact and cable terminations.

**Stranded Conductor**. A conductor composed of a group of smaller wires.

**Stress Relief**. The formed portion of a conductor that provides sufficient length to minimize stress between terminations.

**Strip**. To remove insulation from a conductor.

**Supplier**. In-house NASA, NASA contractors, and subtier contractors.

**Tab Terminal**. A flat-surface terminal that is broad compared to the metal thickness. Wires are often soldered along the flat surface.

**Tang (Connector Backshell).** A backshell tang is a tapering metal projection (straight, 45°, or 90° to the axis of the connector) designed to accommodate cable-tie attachments. The cable-ties grip and hold harness wires exiting from the connector, thus providing stress relief for the wires.

**Tines**. Tines are the members of a contact retention system that capture or "lock" removable crimp contacts into the contact cavities.

**Wicking**. A flow of molten solder, flux, or cleaning solution by capillary action.

**Wire**. A single metallic conductor of solid, stranded, or tinsel construction, designed to carry currents in an electrical circuit. It may be bare or insulated.

**Wire Dress**. The arrangement of wires and laced harnesses in an orderly manner.

### 3.2 Acronyms

The following acronyms apply to terms used in this Standard.

| | |
|---|---|
| **ACS** | American Chemical Society |
| **ANSI** | American National Standards Institute |
| **ASTM** | American Society for Testing and Materials |
| **AWG** | American Wire Gage |
| **CFR** | Code of Federal Regulation |
| **CVCM** | Collected Volatile Condensable Material |
| **DWV** | Dielectric Withstanding Voltage |
| **EEE** | Electrical, Electronic, and Electromechanical |
| **EMI** | Electromagnetic Interference |
| **ESD** | Electrostatic Discharge |
| **ESDS** | Electrostatic Discharge Sensitive |
| **FEP** | Fluorinated Ethylene Propylene |
| **GHz** | Gigahertz |
| **GSFC** | Goddard Space Flight Center |
| **IR** | Insulation Resistance |
| **JPL** | Jet Propulsion Laboratory |
| **MSDS** | Material Safety Data Sheet |
| **NAS** | NASA Assurance Standard |
| **NASA** | National Aeronautic and Space Administration |
| **NASA-STD** | NASA Standard |
| **NHB** | NASA Handbook |
| **OD** | Outside Diameter |
| **OSHA** | Occupational Safety and Health Administration |
| **PET** | Polyethylene Terephthalate |
| **PTFE** | Polytetrafluoroethylene |

| | |
|---|---|
| **PTH** | Plated Through Hole |
| **PVDF** | Polyvinylidene Fluoride |
| **RF** | Radio Frequency |
| **RFI** | Radio Frequency Interference |
| **RH** | Relative Humidity |
| **RMS** | Root Mean Square |
| **SMT** | Surface Mount Technology |
| **TML** | Total Mass Loss |

# CHAPTER 4 - GENERAL

## 4.1 GENERAL

1. **Implementation**. NASA quality assurance personnel will advise and assist suppliers, NASA personnel, and delegated agencies in the proper and effective implementation of the provisions of this publication. Effective implementation includes establishing a system that will identify each inspection point and provide records.

2. **Changes in Requirements**. When related requirements or changes in requirements are specified, NASA quality assurance personnel will assure that the Government agency delegated to inspect at the supplier's site of fabrication has received full instructions so that the work will be inspected to actual contract requirements.

3. **Nonstandard Processes, Materials, or Parts**. When the supplier intends to use processes, materials, or parts not covered by this publication, the supplier shall document the details of fabrication and inspection, including acceptance and rejection criteria, and shall provide appropriate test data. Such documentation shall be approved by the procuring NASA Center prior to use.

## 4.2 Approval of Departures from this Standard

1. Departures from this publication require written approval from the cognizant NASA contracting officer. The supplier is responsible for assuring that any departures from this publication are evaluated by, coordinated with, and submitted to the procuring NASA Center for approval prior to use or implementation.

2. For in-house NASA projects, this publication requires written approval by the in-house NASA project management to deviate from the provisions herein.

## 4.3 Principles of Reliable Cabling and Wiring

1 **Factors Controlling Reliability**. Reliable interconnecting cable and wire harnesses result from proper design, control of tools, materials, work environments, and careful workmanship by trained and certified personnel.

2 **Fabrication Principles**. All fabrication shall be performed to meet governing engineering documentation.

3 **Splicing**. Splicing damaged or broken conductors is not permitted.

4 **Crimping**. Crimping of solid wire and stranded wire that has been solder tinned is prohibited. Stranded wire shall be used.

5 **Design Considerations**. The basic design considerations to assure reliable interconnecting cable and wire assemblies are as follows:

a. The associated materials, parts, and hardware used shall be selected to provide proper fit, function, and support of wiring and cabling.

b. Tools used shall be those that properly process wires and cables during preparation and assembly without damaging them.

c. Wires shall not be taut; provision shall be made for stress relief.

d. Wiring installation and connectors shall be assembled, tested, and inspected to verify conformance to requirements.

e. Support of wiring, wire bundles, and harnesses shall be designed to control and minimize the transfer of shock and vibration induced while loading into the connector and/or wire terminations. Excessive flexing or pressure over sharp or rough edges shall be precluded.

f. Harness and cable protection shall be added in areas where sharp or rough edges are present and abrasion could occur.

## 4.4 Documentation

1. The supplier shall document the methods and procedures proposed to incorporate the requirements of this publication into the design, fabrication, and inspection of cables and harnesses involved in the contract or purchase order.

2. Documents required herein, except as specified by paragraph 4.1-3, shall be submitted to the procuring NASA Center or its designated representative as required by the contract or purchase order. Applicable supplier cabling and harnessing program documents, or portions thereof, accepted on other NASA contracts shall be included whenever possible to avoid duplication of effort.

## 4.5 Rework

1. **Rework**. Rework is permissible unless excluded by other provisions of the contract. All rework shall meet the requirements of this publication and approved engineering documentation.

2. **Repair is not rework**. Repairs shall be made only in compliance with applicable contractual requirements and after authorization for each incident by the procuring NASA Center. Repairs shall be accomplished using documented methods previously approved by the procuring NASA Center. For in-house NASA projects, repairs shall be authorized for each incident by the Project Office and Quality Management, as appropriate.

# CHAPTER 5 - TRAINING AND CERTIFICATION PROGRAM

## 5.1 General

1. The supplier is responsible for maintaining a documented training program that meets the requirements of this Standard.

2. The supplier shall assure that the design personnel are familiar with the requirements of this Standard, crimping, cabling, and harnessing techniques, and other pertinent requirements of the contract. The supplier shall implement and document a training program which provides the necessary training of fabrication and inspection personnel in crimping, cabling, and harnessing requirements and techniques. Use of equipment and procedures pertinent to their responsibilities in performance of the contract requirements shall also be documented. The supplier is responsible for certifying and maintaining the certification of each individual who fabricates, inspects, or instructs.

3. Operators, inspectors, and instructors shall be qualified to fulfill all requirements of this Standard that relate to their assigned tasks. Demonstration of proficiency and understanding of the requirements is a requisite for certification and recertification. Evidence of certification status shall be maintained in the work area.

## 5.2 Vision Requirements

1. The supplier is responsible for ensuring that all personnel who perform or inspect crimping, cabling or harnessing meet the following vision test requirements as a prerequisite to training, certification, and recertification. The vision requirements may be met with corrected vision (personal eyeglasses). The vision tests shall be administered every 2 years by a qualified eye examiner, accepted by the procuring supplier, using standard instruments and techniques. Results of the visual examinations shall be maintained and available for review.

2. The following are minimum vision requirements:

a. **Far Vision**. Snellen Chart 20/50.

b. **Near Vision**. Jaeger 1 at 355.6mm (14 inches) , reduced Snellen 20/20, or equivalent.

c. **Color Vision**. Ability to distinguish red, green, blue, and yellow colors as prescribed in Dvorine Charts, Ishihara Plates, or AO-HRR Tests.

***NOTE:*** ***A PRACTICAL TEST, USING COLOR CODED WIRES AND/OR COLOR CODED ELECTRICAL PARTS, AS APPLICABLE, IS ACCEPTABLE FOR COLOR VISION TESTING.***

## 5.3 Certification Levels

1. Level A NASA instructors are certified by the NASA Training and Certification Board. Level A NASA instructors have the authority to train Level B instructors, operators, and inspectors. Upon successful course completion, a certificate shall be issued.

2. Certification of Level B instructors will be provided by the supplier based on successful completion of the training by a Level A NASA instructor. Level B instructors are authorized to train operators and inspectors employed at their organization and subtier contractors.

3. Certification of inspectors shall be provided by the supplier based on successful completion of the training by a Level A NASA instructor or Level B supplier instructor. An inspector is trained and certified to inspect for conformance with the requirements of this Standard.

4. Certification of operators shall be provided by the supplier based on successful completion of the training by a Level A NASA instructor or Level B supplier instructor. An operator is trained and certified to fabricate cables and harnesses in conformance with the requirements of this Standard. When operators are certified to perform limited operations or processes, it shall be stated on the certification card.

## 5.4 Training Program Requirements

1. The supplier is responsible for training and certification of operators and inspectors in the crimping, cabling, and harnessing processes and associated processing equipment.

2. The supplier training program documentation shall be submitted to the procuring NASA Center as directed by the contract. A NASA Generic Crimping, Cabling, and Harnessing Training Plan from the NASA Training Centers is available for use as a guideline.

3. The training program shall:

a. Identify the criteria for qualification and certification of Level B instructors, operators, and inspectors.

b Document the methods and procedures proposed to fulfill the requirements of this Standard.

c. Utilize visual standards consisting of satisfactory work samples or visual aids that clearly illustrate the quality characteristics of interconnecting cables, harnesses, and wiring applicable to the contract.

d. Utilize applicable illustrations in this Standard, supplemented as necessary, for visual standards. Standards of unacceptable conditions may also be used for clarification or comparison.

e. Make applicable standards readily available.

## 5.5 Documentation

1. The supplier training program documentation shall describe the training and certification program proposed to satisfy the requirements herein for the types of cables and harnesses to be made. This description shall include the following, as applicable:

a. Qualifications of instructors.

b. Procedures for training, including who will be trained and for what purpose, (e.g., operator, inspector).

c. Lesson plan(s)/student standards.

d. Hours of instruction.

e. Procedures for certification and recertification.

f. Procedures for recording training, recertification, and method of identifying/recalling trained personnel.

g. Certification criteria.

2. Records of training and certification shall become part of the supplier's quality data and shall be retained for a minimum of 5 years.

3. Evidence of certification status, including limitations, shall be available in the work area.

## 5.6 Maintenance of Certification Status

1. Maintenance of certification for instructors, operators, and inspectors requires continuous proficiency.

2. Recertification of Level B instructors shall include the successful completion of retraining by a Level A NASA instructor. Recertification of operators and inspectors shall include successful completion of retraining by a Level A NASA instructor or a Level B supplier instructor.

3. Recertification shall be required when:

a. Proficiency requirements herein are not met.

(1) Instructors - proficiency unacceptable.

(2) Operators - unsatisfactory quality of articles fabricated.

(3) Inspectors - unsatisfactory quality of inspection.

(4) Quality/quantitative data demonstrates a need for recertification.

b. New fabrication or inspection techniques have been approved that require different skills.

c. Work period interruption of greater than 6 months occurs.

d. Two years has elapsed since last certification.

4. Certification shall be revoked when:

a. Certificate holder fails recertification.

b. Certificate holder fails to meet visual acuity requirements of paragraph 5.2.

c. Employment is terminated.

d. Supplier training program fails to meet requirements set forth herein or set forth otherwise in the contract.

## 5.7 Training Resources

1. Training of Level B instructors is available at either the Goddard Space Flight Center (GSFC) or Jet Propulsion Laboratory (JPL). The NASA Generic Crimping, Cabling, and Harnessing Training Plan will be supplied to instructors at the time of course completion.

a. GSFC
Training Center
Code 300.1
Greenbelt, MD 20771
(301)731-8632
FAX (301)731-8628

b. JPL
Training Center
MS83-204
4800 Oak Grove Drive
Pasadena, CA 91109
(818)354-6730
FAX (818)393-0090

2. Suppliers may train operator or inspector personnel in-house for certification or recertification utilizing certified instructors and approved training programs, or arrange for this training at one of the NASA-conducted schools.

3. A fee is required. Contact either training center for information.

# CHAPTER 6 - FACILITIES, EQUIPMENT, MATERIALS, AND PARTS

## 6.1 Facility Cleanliness

The work area shall be maintained in a clean and orderly condition. Smoking, eating, and drinking at individual work stations shall not be permitted. Nonessential tools and materials shall not be permitted at the work station.

## 6.2 Environmental Conditions

1. **Controlled Environment.** The cabling and wiring area shall have a controlled environment, which limits the entry of contamination. The temperature and humidity of this area shall be monitored, documented, and maintained within the limits defined as the comfort zone in Figure 6-1

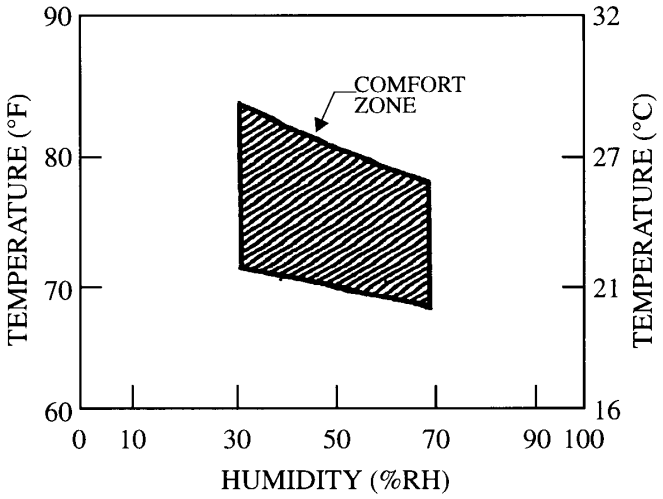


**Figure 6-1. Comfort Zone--Temperature Versus Humidity Requirements**

2. **Special Environmental Requirements.** Parts or equipment being processed that require more stringent control of environmental conditions than those stated above shall have these requirements and controls identified and specified in the engineering documentation.

3. **Ventilation System.** Areas used for cleaning parts, and areas where toxic or volatile vapors are generated, shall have a ventilation system for removing air contaminants. The ventilation system shall comply with the recommendations and guidelines of the Occupational Safety and Health Administration (OSHA) requirements, 29 CFR Part 1910.

4. **Field Operations Requirements.** In field operations where the required controlled conditions cannot be effectively achieved, special precautions shall be taken to minimize the effects of the uncontrolled environment on the operation being performed on the hardware. These precautions shall be identified in the appropriate documentation.

5. **Lighting.** Light intensity shall be a minimum of 1077 lumens per square meter ($lm/m^2$) (100 foot-candles) on the surface where cabling and wiring are being assembled, inspected, or tested. Supplemental lighting may be used to achieve the required lighting levels.

## 6.3 Tool and Equipment Control

1. Each supplier shall:

a. Select tools to be used for crimping, cabling, wiring, and in work preparation areas appropriate to the intended function.

b. Clean and properly maintain all tools and equipment.

c. Examine all elements of tools, used in cabling, for physical damage.

d. Prohibit unauthorized, defective, or uncalibrated tools in the work area.

e. Document detailed operating procedures and maintenance schedules for tools and equipment requiring calibration or set ups. Maintain records of tool and equipment calibration and functional testing.

2. The supplier shall have a documented calibration system in accordance with ANSI/NCSL Z540-1-1994. The minimum standard shall be:

a. Measurement standards used for calibrating tools shall be traceable to National Institute of Standards and Technology (NIST). Calibration of tools shall be performed in an environment compatible with the environmental requirements of the tools.

b. Calibration intervals shall be based on the type of tool and records of the tool's calibration. Intervals may be lengthened or shall be shortened on the basis of stability demonstrated over previous calibration periods.

c. Procedures shall be generated and utilized for the calibration of all tooling stated herein. Procedures shall include, as a minimum, standards to be used, parameters to be measured, accuracy, tolerances, environmental factors, and steps in the calibration process. The procedures may be the manufacturer's specifications if judged adequate, and need not therefore be rewritten, but shall be documented.

d. Records shall be maintained that document the calibration.

e. Tools shall be labeled to indicate, as a minimum:

(1) Date of calibration.

(2) Calibration due date.

(3) Any limitation of use. If not practical to place the label directly on the tool, then the label shall be affixed to the tool container.

(4) The identification of the organization performing the calibration.

(5) Tool identification.

(6) Traceability on the tool to the container if the container contains the calibration label.

f. Power tools used during the cabling process shall comply to the tool requirements herein and have a three-wire grounded power cord or be double insulated. The area making contact with the workpiece shall be grounded. When measured from the workpiece contact point to ground, the resistance shall not exceed 2.0 ohms and the potential difference shall not exceed 2 millivolts Root Mean Square (RMS) using methods indicated in the supplier's engineering documentation.

3. The supplier's process documentation for tool control is subject to review and approval by the procuring NASA Center. Suppliers may elect to use tools not mentioned in this Standard provided the engineering documentation is reviewed and approved by the procuring NASA Center prior to use.

## 6.4 Electrostatic Discharge Requirements

The supplier shall implement an electrostatic discharge (ESD) Control Program for any activity that tests, inspects, services, manufacturers, installs, packages, labels or otherwise processes ESD sensitive parts or assemblies. ESD requirements shall be in accordance with NASA-STD-8739.7 or other approved ESD control procedures. All personnel who handle static-sensitive parts and assemblies shall have been trained in the proper procedures and in the use of appropriate protective equipment to prevent ESD damage.

## 6.5 In-Process Storage and Handling

Each supplier performing cabling and harnessing operations shall develop and implement requirements and procedures that control conditions to prevent damage to and degradation of parts and deliverable terminating areas, terminals, connectors, wire ends, or part leads during handling and storage. Containers shall be compatible with materials stored therein.

## 6.6 Wire Processing and Preparation Tools

The supplier shall select and use the following conductor preparation tools:

1. **Strippers**. Either precision mechanical tools or thermal strippers shall be selected for insulation stripping. Thermal strippers shall have variable temperature control. The tools shall not nick, ring, gouge, or stretch conductors or remove plating so that the base metal shows. Superficial scraping of conductors is acceptable providing conductor base material is not exposed.

2. **Wire Cutters**. Wire cutting tools that shear the conductor shall be selected in preference to diagonal cutters that cut the conductor by bringing two blade edges together. The cutting edges of wire trimming tools shall be maintained sharp and free from nicks and indentations.

3. **Torque Tools**. Torque tools shall be calibrated and shall utilize drive sockets and attachments appropriate for the hardware being torqued.

## 6.7 Inspection Optics

Visual inspection shall be performed using magnification aids conforming to the following:

1. Inspection magnification aids that permit simultaneous viewing with both eyes are preferred, but single eye viewing devices are acceptable.

2. Magnification aids shall be capable of rendering true colors, proportional dimensions, and adequate resolution at the chosen magnification to perform the specified inspection.

3. The light source shall provide shadowless illumination of the area being viewed.

## 6.8 Materials Selection

All materials used in vacuum or low-pressure compartments shall not release greater than 1.0 percent total mass loss (TML) or 0.1 percent collected volatile condensable material (CVCM) when tested in accordance with ASTM-E-595. All materials used in habitable areas of spacecraft, stowed equipment, and experiments shall be evaluated for flammability, odor, and offgassing characteristics in accordance with NHB 8060.1. Materials used shall be subjected to NASA approval. All material shall be selected to conform to the project contamination control requirements plan.

## 6.9 Solvents and Cleaners

1. **Solvent Requirements.** Solvents shall be nonconductive and noncorrosive and shall not dissolve or degrade the quality of parts or materials. Solvents shall be properly labeled and shall be maintained in a clean and uncontaminated condition. Solvents showing evidence of contamination or decomposition shall not be used. Solvents and cleaners shall not leave a residue or contamination in parts or materials. Refer to the Material Safety Data Sheets (MSDS) for proper handling of solvents.

2. **Acceptable Solvents.** The following solvents are acceptable when used for cleaning connectors, hardware, and other materials and parts in cables and harnesses. Other solvents require approval of the procuring activity prior to use.

   a. Ethyl alcohol, 0-E-760, Types III, IV, or V.

   b. Isopropyl alcohol, TT-I-735.

3. **Part Marking Permanency**. Solvent and cleaning systems have the potential of removing marking information from parts. Appropriate marking permanency testing shall be performed as part of the evaluation procedure for any solvent or cleaning system.

***WARNING:*** ***SOLVENTS USED IN THE HARNESS AND CABLE MANUFACTURING PROCESS CAN BE HAZARDOUS AND VOLATILE. THESE MATERIALS SHALL BE USED IN ACCORDANCE WITH THE RECOMMENDATIONS AND GUIDELINES OF THE INDUSTRIAL VENTILATION MANUAL OF RECOMMENDED PRACTICES AND THE OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA), 29 CFR.***

### 6.10 Personnel Protection

Personal protective equipment shall be provided as appropriate for the work being performed. Protective equipment shall comply with the requirements of OSHA, 29 CFR Part 1910.

# CHAPTER 7 - DESIGN PRACTICES

## 7.1 General

Connectors, wires, and hardware shall be selected from MIL-STD-975 or as specified by the contract. Harness design shall make provision for special performance requirements of any specific harness section (e.g., ease of bending, flexibility in twisting, electrical isolation, and ability to fit into confined spaces). Design considerations should include protective devices such as heat-shrinkable sleeving for protection, stress relief, electrical insulation, and identification purposes.

Precautions shall be taken to prevent the mismating of connectors, caused by interchanging or by reversing, through one of the following techniques:

1. Use of constraints that locate similar connectors built into interconnecting cables and harnesses so they cannot be interchanged.
2. Selection of different sizes for connectors to be located adjacent to each other.
3. Polarization or dissimilar keying of adjacent, similar connectors.
4. Ensure clarity in marking and coding connectors.
5. Use of confidence loop circuits to check out proper mated positions.

## 7.2 Requirements Not Covered

Other processes, such as potting and molding, not covered by this document may be required to fabricate cables and harnesses. The design, materials, and processes shall be defined in engineering documentation.

## 7.3 Design Considerations

The following considerations shall be taken in any interconnecting cable or harness design and incorporated into the design as applicable:

1. Current and voltage derating of conductors as determined by MIL-STD-975 or as specified in the engineering documentation.
2. Voltage drop considerations.
3. Availability of spare connector contacts (facilitates circuitry changes).
4. Properties of wire insulation, lacing tape, braid sleeving, plastic strap, wrap sleeving, and plastic tubing (processibility, flammability, arc tracking resistance, vacuum stability, resistance to heat, cold flow, etc.) as appropriate for the application. Plastic straps should have metal tangs that lock securely into the "ribbed" portion of the straps.
5. Tin-plated parts (e.g., terminals, crimp barrels, etc.) must be fused or alloyed with tin-lead plating.

6. Methods of identifying cables, connectors, and wires and their effects on environmental requirements.

7. Radio frequency interference/electromagnetic interference (RFI/EMI) shielding requirements.

8. Operation of circuits through critical pressure (require that potentials in excess of 200 Vac or 300 Vdc be terminated in a single-contact, high voltage connector).

9. Electrical wiring of redundant systems, redundant subsystems, or redundant major elements of subsystems shall not be routed in the same bundle or through the same connector with wiring of the other system, subsystem, or subsystem element.

10. Separate handling of radio frequency (RF) signals in coaxial cable and RF connector assemblies.

11. Materials and wiring design to meet NHB 8060.1, Flammability, Odor, Offgassing and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion.

12. American wire gage (AWG) 24 wire size and larger is preferred for conductors in interconnecting cable and harness assemblies, including coaxial or triaxial cables. High strength copper alloy shall be used for AWG 24 and smaller conductors. When high strength copper alloy wire is used, a magnetic survey of the installation shall be conducted if project requirements indicate a sensitivity to magnetic interference.

13. Torque values applicable for connectors, backshells, and other hardware.

14. Route and support harnesses and cables so that they are protected from abrasion, cold flow, cut through, vibration, chafing, flexing, and sharp edges.

15. Design minimization of splicing.

16. Protection of all electrical terminations to withstand the operating environment.

17. Preconditioning using thermal cycling prior to preparation for connectorization in high frequency applications using semi-rigid coaxial cable. This procedure should also be considered for longer runs of flexible coaxial cable.

18. Confining line voltages to connectors with sockets to preclude exposing voltage points when connectors are disconnected.

19. Specifying the use of sealing plugs and unused contacts in environmental connectors.

20. Fabricate cables containing discrete wires in one or more layers by winding the wires together uniformly. Whether successive layers are twisted contrahelically or unidirectionally is optional. Winding shall prevent the introduction of residual twist into individual conductors. The length of lay for each layer shall be between 8 and 16 times the outer diameter of the harness.

21. The bend radius data given in Table 7-1 shall apply for bending that occurs in the installed interconnecting harness or cable.

22. Wires exiting from connectors shall be stress relieved.

23. The use of solder sleeves (where wire insulation temperatures permit), hand soldering, or crimp rings are acceptable for terminating individual shields.

24. Concern for placement of power and ground lines in contact assignments for system safety.

25. Materials for potting connectors suited for applications.

26. Selection of metal braid shielding should be sized as appropriate per application.

**Table 7-1. Bend Radii for Completed Interconnecting Cable or Harness**

| Wire Type | Optimum Bend Radius | Minimum Bend Radius |
|---|---|---|
| Individual coaxial cable. | 10 x OD 1/ | 6 x OD |
| Polyimide (Kapton) insulated | 15 x OD | 10 x OD |
| Overall harness (with coaxial cable or AWG size 8 or larger). | 10 x OD | 6 x OD |
| Overall harness (with AWG size 10 or smaller without coaxial cable). | 10 x OD | 3 x OD |
| Overall harness (with polyimide insulated wires included). | 15 x OD | 10 x OD |

1/Outside Diameter

# CHAPTER 8 - INTERCONNECTING CABLE/HARNESS FIXTURING

## 8.1 General

Layout and fixturing shall be provided for all complex interconnecting cables and harnesses. Permanent bends and offsets shall be built into harnesses so that the final wire dress will not be under continuous stress and tension after installation. Connector back shells shall accommodate bends and offsets in wire harnesses, as appropriate, to avoid continuous stress. Additionally, the layout shall be designed to limit the amount of bending, pulling, and other handling a harness will receive during installation.

## 8.2 Mockup and Wiring Board Design Parameter

Wiring boards and other mockups shall be constructed full size, 3-dimensional, and shall account for all the physical restraints the interconnecting harness or cable will encounter. Typical harness board layout and typical hardware and fixtures are shown in Figures 8-1 and 8-2, respectively.

## 8.3 Temporary Identification

Temporary identification markers may be used for in-process identification requirements. All temporary markers shall be removed from completed cabling and harnessing. The markers shall not leave a contaminating residue.

## 8.4 Interconnecting Cable and Harness Protection

The supplier shall establish and implement procedures to protect interconnecting cables and harnesses from damage and degradation. Connectors not being actively assembled shall be individually protected by wrapping them in bubble pack or other physical covering. At the end of the work shift, protective covering shall be spread over the harnesses in fabrication. Harnesses not in active fabrication (those in temporary storage) shall be covered by protective covering (Electrostatic Discharge (ESD) protective covering in accordance with NASA-STD-8739.7 if Electrostatic Discharge Sensitive (ESDS) parts are utilized).

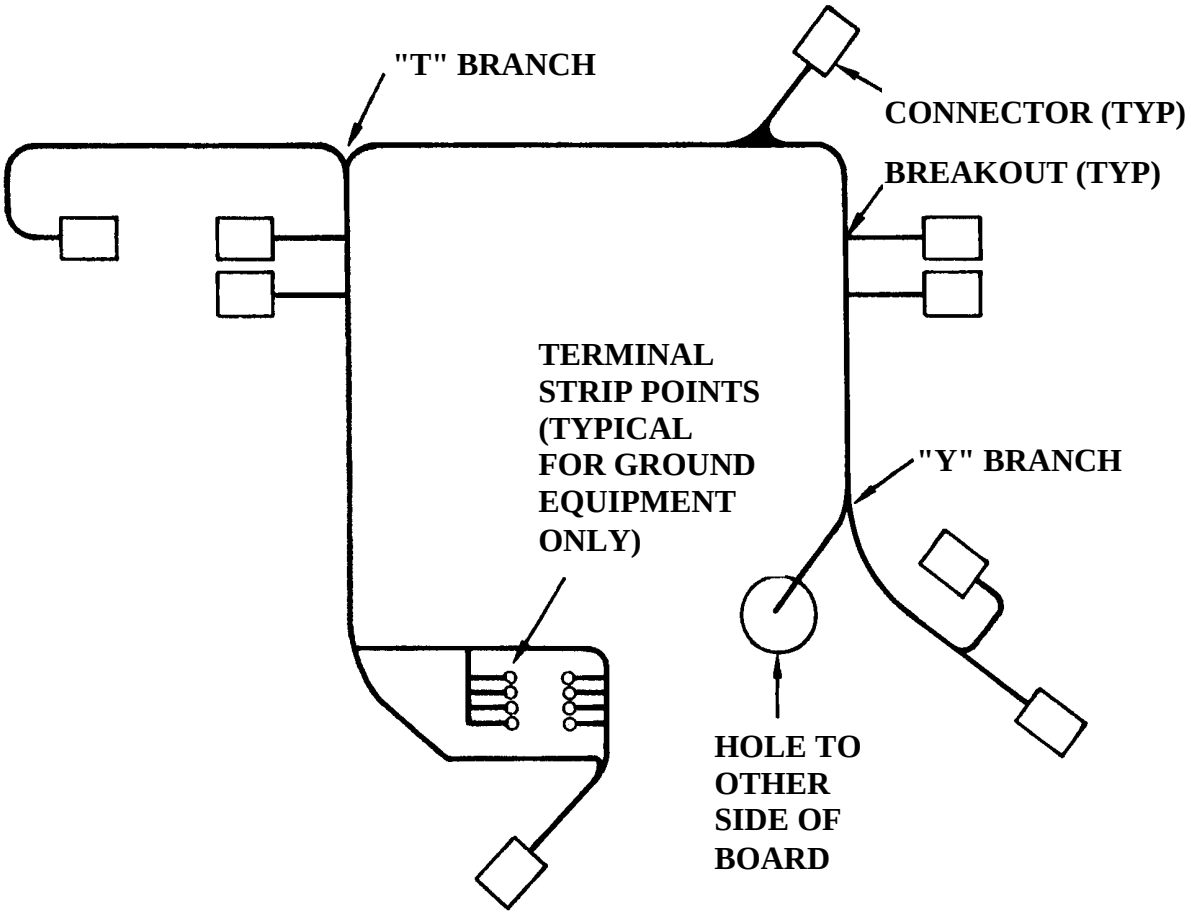


**Figure 8-1. Line Drawing of Typical Harness Layout**

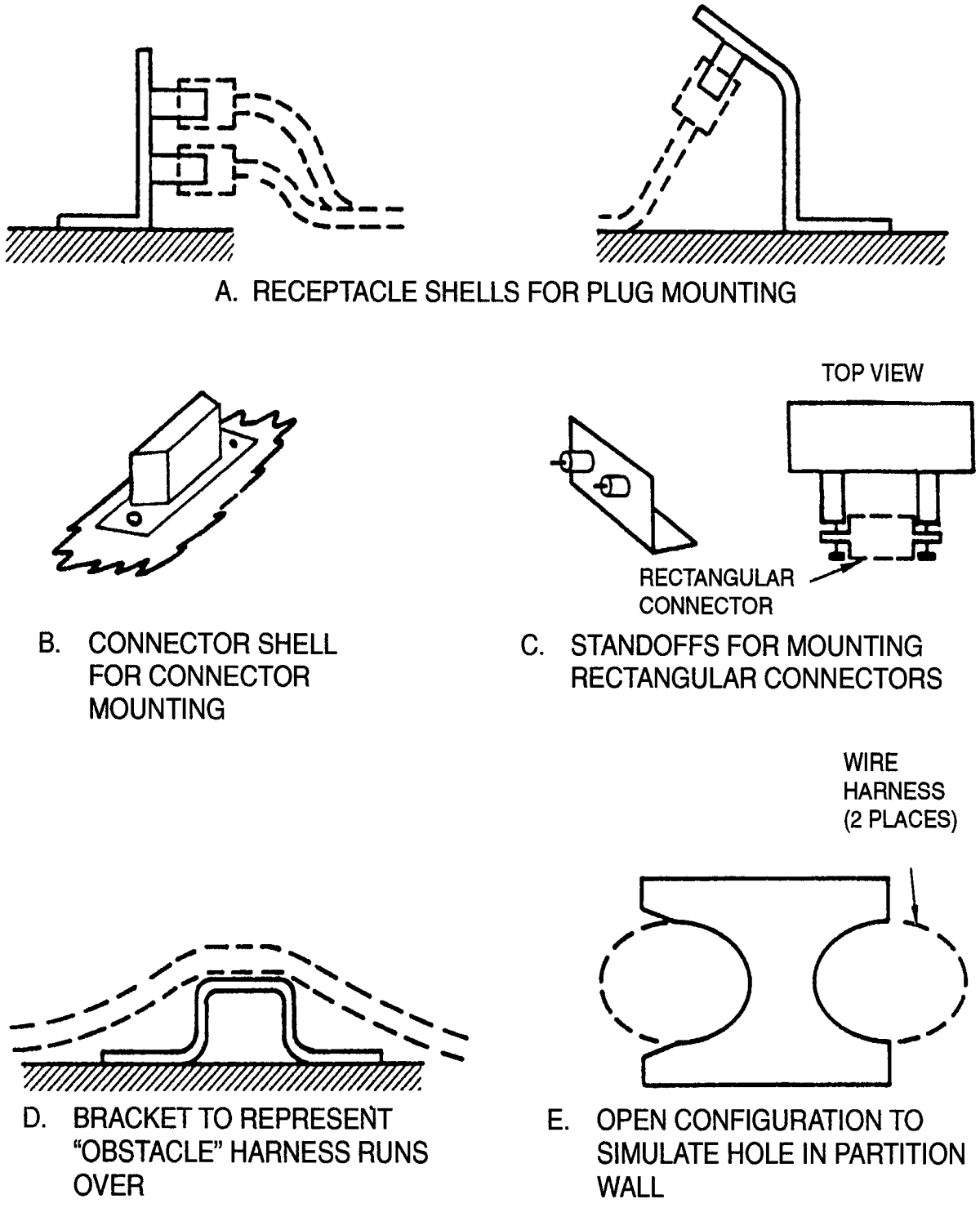


**Figure 8-2. Typical Harness Board Hardware and Fixtures**